Trade, Status, Population Growth, and Environment in Developing Countries

Ulla Lehmijoki Tapio Palokangas

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Abstract

This paper examines per capita pollution in a developing economy by a family-optimization model where fertility is endogenous and wealth increases welfare through status effect. Developing countries have weaker environmental laws and specialize in capital-intensive "dirty" goods. With a significant status effect, gains from trade stimulate investments leading to higher wages so that population growth first increases but then decreases. The opposite changes in labor supply first swell but then curb the production of the capital-intensive dirty good. A typical EKC path appears: per capita pollution increase at the earlier but decrease at the later stages of development.

Journal of Economic Literature: Q56, O41, J13

Keywords: international trade, status, population growth, development

Addresses of the Authors: Ulla Lehmijoki, Valkjarventie 13 02130 Espoo, Finland. (email: Ulla.Lehmijoki@helsinki.fi) – Tapio Palokangas, Department of Economics, P.O. Box 17 (Arkadiankatu 7), FIN-00014 University of Helsinki, Finland. Phone (email: Tapio.Palokangas@helsinki.fi)

1 Introduction

Has trade liberalization any impact on pollution in developing countries? Will the Environmental Kuznets Curve appear in poor countries? The "pessimists" argue that free trade transfers pollution-intensive production from rich countries to poor countries, whereas the "optimists" claim that gains from trade help the poor countries to reach the EKC peak, after which pollution decreases. In this paper, we show that both perspectives are in some respect correct, but alone insufficient to explain the complicated demographic, labor market, and environmental dynamics in developing countries, triggered by the liberalization of trade. Free trade changes labor supply through population growth which, together with capital accumulation, first increases but then decreases environmental degradation.

In the earlier literature, Arrow et al. (1995) suggest that the EKC path arises because in poor countries, people "cannot afford environmental amenities over material well-being but ... in richer countries people give more attention to environmental quality". Selden and Song (1994) and Grossman and Krueger (1995) argue that EKC may result from the interaction of the scale, composition, and technology effects, as forces leading to cleaner composition of goods and techniques outweigh the adverse effects of growing economic activity. Pasche (2002) and Kelly (2003) claim that since latest vintages of capital are less pollution intensive, capital accumulation and gradual technical progress together may decrease emissions. John and Pecchenino (1994) maintain that poor economies don't engage environmental investments but free-ride at the cost of future generations, whereas Stokey (1998) shows that intergenerational conflict calls for governmental activities for EKC to arise.

In this paper, we concentrate on the demographic and environmental changes induced by the post-war liberalization of world trade, which increased trade volumes by an annual average that was close to ten per cent initially and somewhat lower after the oil crises (Maddison 2001). Simultaneously, population growth in developing countries accelerated to unprecedented numbers to peak around the 1970s and to decrease soon after. The highest numbers, close to four per cent, were reached in the poorest countries.

Our theory derives of three elements. The first of them is the comparative advantage in trade. Because pollution-intensive goods are capital-intensive as well, the capital-rich industrial countries would have the comparative advantage in dirty goods with uniform environmental laws,(Cole and Elliot 2003 and 2005). According to the Pollution Havens hypothesis, however, this advantage is in poor countries because their legislation in terms of environment is weak (Antweiler et al. 2001, Copeland and Taylor 2004).[1] Consequently, poor countries specialize in the capital-intensive dirty goods (Suri and Chapman 1998, Cole and Elliott 2003, Mani and Jha 2006).

The second element is demographic. According to the theory of endogenous fertility (Becker 1981), the demand for children results from two opposing effects: the income effect and the substitution effect. Because children are normal goods, the income effect is positive, but because high wages increase the opportunity costs for children, the substitution effect is negative. With liberalization, these effects operate as follows. In the short run, gains from trade raise fertility through the income effect. They also generate savings and capital accumulation, which raise wages and decrease fertility in the long run (Lehmijoki and Palokangas 2007). This long-run effect, however, is sensitive to saving incentives in developing countries. If these are low, gains from trade manifest themselves as long-lasting population growth and the country stagnates to a high-fertility, low-capital poverty trap (Galor and Mountford 2006). But if saving incentives are high and capital accumulation gets started, then population growth first increases and then decreases. Hence, labor supply falls initially with the "migration" of women to child rearing, but then it rises, as both the grown-up children and their parents enter the labor force (Bloom and Williamson 1998).

The third element is the Rybczynski theorem: given full employment of both capital and labor, the initial decrease in labor supply curbs the labor-intensive clean sector but expands the capital-intensive dirty sector which, because of the investments, may swell ever more at early stages of development (Rybczynski 1955). But because capital accumulation attracts people from home to production through higher wages, labor-intensive clean sector expands and ultimately crowds out the capital-intensive dirty sector. This generates a typical EKC path: per capita pollution increases at the earlier stages of development but decreases at the later stages.

[1] Several articles on Pollution Havens are collected and reprinted in Fullerton (2006).

Empirical evidence on trade and pollution is somewhat mixed. Suri and Chapman (1998) support the pessimistic view by showing that richer countries have reduced their energy requirements since they import the energy-intensive goods from poorer countries. Because energy consumption is one of the main sources of pollution, this has increased pollution in poorer countries. Mani and Jha (2006) document a considerable shift in Vietnamese export toward pollution intensive manufacturing goods (leather and textiles) after the liberalization of trade. On the other hand, Jha et al. (2006) have carried out case studies in poor countries and they support the optimistic view that gains from trade will provide enough resources for environmental protection. A rigorous empirical analysis is outside the scope of this paper but we provide some anecdotal evidence to test our theory. The main finding is that trade liberalization induces a peak in population growth that, after a lag of one generation, is followed by a similar peak in per capita pollution. Remembering the inverse relationship between population growth and labor supply, this pattern seems to support our theory.

This study is organized as follows. Section 2 provides a family-optimization model in a small open developing economy in which trade liberalization shows up as a price increase in its dirty export good. Section 3 constructs the dynamics of the model. Short-run and long-run effects are analyzed in Sections 4 and 5 with the result that, after liberalization, per capita pollution first increases and then decreases. Section 6 discusses the anecdotic evidence and Section 7 closes the paper.

2 The model

We denote population in the economy by L. Mortality and aging is ignored, for simplicity, so that the number of newborns is equal to the change of population $\dot{L} = dL/dt$, where $(\dot{})$ denotes the derivative with respect to time t. We assume that the rearing of each newborn requires a fixed amount q of labor. The population growth rate is then given by

$$n \doteq \dot{L}/L \tag{1}$$

and the total labor in child rearing by $q\dot{L} = qnL$. The labor supply in the market is then equal to population minus labor in child rearing, $L - qnL$.

We assume that the economy consists of two sectors: the *dirty sector* and the *clean sector* with outputs A and B respectively. Kelly (2003) defines three different measures of pollution: the stock of pollutants, the intensity of control policy, and emissions. We use emissions, because they can be easily incorporated into a model of population growth and international trade. Because emissions must be an increasing function of the output of the dirty sector, A, we use A as an index of emissions. Both sectors produce their outputs from labor and capital through Leontief technology:

$$A = \min[K_a/\alpha_a, L_a/\beta_a], \quad B = \min[K_a/\alpha_a, L_a/\beta_a],$$

where A (B) is output, K_a (K_b) capital input and L_a (L_b) labor input in the dirty (clean) sector, and α_a, α_b, β_a and β_b are constant and positive production coefficients. This leads to the equilibrium conditions

$$K_a = \alpha_a A, \quad K_b = \alpha_b B, \quad L_a = \beta_a A, \quad L_b = \beta_b B. \tag{2}$$

We assume that the dirty sector is more capital intensive:

$$\alpha_a/\beta_a = K_a/L_a > K_b/L_b = \alpha_b/\beta_b \text{ and } \alpha_a\beta_b > \alpha_b\beta_a. \tag{3}$$

Capital and labor are freely transferable between the sectors. Noting (2), this yields

$$K = K_a + K_b = \alpha_a A + \alpha_b B, \quad L - qnL = L_a + L_b = \beta_a A + \beta_b B, \tag{4}$$

where K is capital stock and $L - qnL$ the labor supply in production. We normalize the output price in the clean sector at unity. Solving for A and B from (4) yields

$$A = \frac{\beta_b K - \alpha_b(1-qn)L}{\alpha_a\beta_b - \alpha_b\beta_a}, \quad B = \frac{\alpha_a(1-qn)L - \beta_a K}{\alpha_a\beta_b - \alpha_b\beta_a}.$$

Noting this and (3), the per capita outputs are linear functions

$$\begin{aligned} &A/L \doteq a(k,n), \;\; a_k > 0, \;\; a_n > 0, \;\; a - a_n n = a\big|_{n=0} > 0, \\ &B/L \doteq b(k,n), \;\; b_k < 0, \;\; b_n < 0. \end{aligned} \tag{5}$$

where the lower case letters a, b, and k stand for per capita variables and the subscripts stand for the partial derivatives respectively.

Because of lax environmental legislation, the developing economy exports the dirty good. The economy is so small that the (relative) price of the dirty good, p, is given from abroad. National income per capita is then given by the function

$$y(k,n,p) = pa + b, \;\; y_k(p) \doteq \frac{\partial y}{\partial k} > 0, \;\; y_n(p) \doteq \frac{\partial y}{\partial n} < 0, \;\; y_p \doteq \frac{\partial y}{\partial p} = a. \tag{6}$$

We assume that the output A of the dirty sector is produced only for exports, for simplicity. The domestic consumption of this good would complicate the analysis without adding any essential results.

Following Razin and Ben-Zion (1975) and Becker (1981), we consider a representative family that derives utility from per capita consumption c and the number of children that can be proxied by population growth $n \doteq \dot{L}/L$. Because capital is the only asset in the model, total wealth is equal to capital K. In addition to consumption and children, the families benefit also from their status in society. Therefore, following Kurz (1968), Corneo and Jeanne (1997, 2001), Chang et al. (2000), Pham (2005), Fisher (2005) and Fisher and Hof (2005), we augment the utility function by inserting the per capita wealth of the family itself, $k \doteq K/L$, over and above the average per capita wealth in the economy, κ. Hence, the representative family's discounted utility at time $t = 0$ is specified as follows:

$$U = \int_0^\infty \big[\log c + \theta \log n + \varepsilon v(k - \kappa)\big] e^{-\rho t} dt, \;\; v' > 0, \;\; v'' < 0, \;\; v'(0) = 1, \tag{7}$$

where $\rho > 0$ is the constant rate of time preference, $v(k - \kappa)$ the proxy for the status of the family, and $\theta > 0$ and $\varepsilon > 0$ are the constant weights for children and status respectively.

On the assumption that capital is the only asset in the economy, the family budget constraint can be written in terms of its accumulation as follows:

$$\dot{K} \doteq dK/dt = yL - cL, \tag{8}$$

where $\dot{K} \doteq dK/dt$ is saving (= capital accumulation), yL total income and cL total consumption of the family. Noting (5) and (6), the budget constraint (8) can be expressed in per capita terms as:

$$\dot{k} = \frac{\dot{K}}{L} - \frac{K}{L}\frac{\dot{L}}{L} = y(k,n,p) - c - nk. \tag{9}$$

3 Dynamics

Given the behavior of the families, we consider the effects of an exogenous increase in the relative price p of the dirty good. This results from opening up trade and the initial specialization of the economy to the capital intensive dirty good A. We construct the patterns of the capital-labor ratio k and per capita emissions a.

The representative family maximizes its utility (7) by per capita consumption c and the number of children, n, subject to its budget constraint (9). The Hamiltonian corresponding to this is given by

$$H = \log c + \theta \log n + \varepsilon v(k - \kappa) + \lambda\big[y(k, n, p) - c - nk\big], \tag{10}$$

where, noting (6), the co-state variable λ evolves according to

$$\dot{\lambda} = \rho\lambda - \frac{\partial H}{\partial k} = [\rho + n - y_k(p)]\lambda - \varepsilon v'(k - \kappa), \quad \lim_{t\to\infty} \lambda k e^{-\rho t} = 0. \tag{11}$$

Noting (6), the first-order conditions of this maximization are given by

$$\frac{\partial H}{\partial c} = \frac{1}{c} - \lambda = 0, \quad \frac{\partial H}{\partial n} = \frac{\theta}{n} + \lambda[y_n(p) - k] = 0. \tag{12}$$

We replace λ by per capita emissions a as the co-state variable, for convenience. Using (5), the population growth rate n can be written as a linear function

$$n(k, a), \quad n_k \doteq \partial n/\partial k < 0, \quad n_a \doteq \partial n/\partial a > 0. \tag{13}$$

Noting (5), (12) and (13), we obtain per capita consumption c as follows:

$$\begin{aligned} &c = \frac{1}{\lambda} = \frac{1}{\theta} z(k, a, p), \quad z(k, a, p) \doteq n(k, a)[k - y_n(p)], \quad z_k \doteq \frac{\partial z}{\partial k} = n + \frac{z}{n} n_k, \\ &z_a \doteq \frac{\partial z}{\partial a} = \frac{z}{n} n_a > 0, \quad z_p \doteq \frac{\partial z}{\partial p} = -n \frac{\partial^2 y}{\partial n \partial p} = -n a_n < 0, \\ &a + z_p = a - a_n n > 0. \end{aligned} \tag{14}$$

An increase in per capita wealth k has two opposite effects on consumption $c = z/\theta$:

(i) Per capita wealth increases consumption.

(ii) Because an increase in wealth raises capital and wages, it attracts labor from child rearing to production and the population growth rate falls. Because children and consumption are complements in preferences, consumption falls as well.

We assume that the wealth effect (i) dominates over the wage effect (ii), so that an increase in wealth raises consumption:

$$z_k > 0. \tag{15}$$

Inserting the functions (13) and (14) into (9), we obtain capital accumulation as a function of (k, a, p) as follows:

$$\dot{k} = y(k, n(k, a), p) - z(k, a, p)/\theta - n(k, a)k.$$

This function has following properties:

$$\begin{aligned} &\frac{\partial \dot{k}}{\partial k} = y_k + (y_n - k)n_k - \frac{z_k}{\theta} - n = y_k - \Big(1 + \frac{1}{\theta}\Big) z_k, \\ &\frac{\partial \dot{k}}{\partial a} = (y_n - k)n_a - \frac{z_a}{\theta} = -\Big(1 + \frac{1}{\theta}\Big) z_a < 0, \quad \frac{\partial \dot{k}}{\partial p} = y_p - \frac{z_p}{\theta} = a - \frac{z_p}{\theta} > 0. \end{aligned} \tag{16}$$

If we assume that all families in the economy are similar, in equilibrium all families have the same per capita wealth, $\kappa = k$. Given $\kappa = k$, (7) and (13), we can transform the differential equation (11) into

$$\begin{aligned} &\rho + n(k, a) - y_k(p) - \frac{\varepsilon}{\theta} z(k, a, p) \\ &= \rho + n - y_1 - \frac{\varepsilon}{\lambda} v'(0) = \dot{\lambda}/\lambda = -\dot{z}/z = -(z_k/z)\dot{k} - (z_a/z)\dot{a}. \end{aligned}$$

Rearranging terms and noting (6), (14) and (16), we obtain the change of per capita emissions, $\dot{a}$, as a function of the variables (n, k, p) as follows:

$$\dot{a} = \frac{z}{z_a}\left[\frac{\varepsilon}{\theta} z(k, a, p) + y_k(p) - n(k, a) - \rho\right] - \frac{z_k}{z_a}\dot{k}$$

with

$$
\begin{aligned}
&\left.\frac{\partial \dot a}{\partial p}\right|_{\dot k=\dot a=0} = \frac{z}{z_a}\left[\frac{\varepsilon}{\theta}z_p + a_k\right] - \frac{z_k}{z_a}\frac{\partial \dot k}{\partial p} = \frac{z}{z_a}\left[\frac{\varepsilon}{\theta}z_p + a_k\right] - \frac{z_k}{z_a}\left[a - \frac{\varepsilon}{\theta}\frac{z_p}{\varepsilon}\right],\\
&\lim_{(\theta/\varepsilon)\to 0}\left.\frac{\partial \dot a}{\partial p}\right|_{\dot k=\dot a=0} = \left(\frac{z}{z_a} + \frac{z_k}{\varepsilon z_a}\right)\frac{\varepsilon}{\theta}z_p < 0,\\
&\left.\frac{\partial \dot a}{\partial k}\right|_{\dot k=\dot a=0} = \frac{z}{z_a}\left[\frac{\varepsilon}{\theta}z_k - n_k\right] - \frac{z_k}{z_a}\frac{\partial \dot k}{\partial k} = \frac{z}{z_a}\left[\frac{\varepsilon}{\theta}z_k - n_k\right] - \frac{z_k}{z_a}\left[y_k - \left(1 + \frac{1}{\varepsilon}\frac{\varepsilon}{\theta}\right)z_k\right],\\
&\left.\frac{\partial \dot a}{\partial a}\right|_{\dot k=\dot a=0} = \frac{z}{z_a}\left[\frac{\varepsilon}{\theta}z_a - n_a\right] - \frac{z_k}{z_a}\frac{\partial \dot k}{\partial a} = \frac{z}{z_a}\left[\frac{\varepsilon}{\theta}z_a - n_a\right] + \left(1 + \frac{1}{\varepsilon}\frac{\varepsilon}{\theta}\right)z_k,\\
&\lim_{(\theta/\varepsilon)\to 0}\left.\frac{\partial \dot a}{\partial k}\right|_{\dot k=\dot a=0} = \left(1 + \frac{z_k}{\varepsilon z}\right)\frac{z}{z_a}\frac{\varepsilon}{\theta}z_k > 0,\quad \lim_{(\theta/\varepsilon)\to 0}\left.\frac{\partial \dot a}{\partial a}\right|_{\dot k=\dot a=0} = \left(1 + \frac{z_k}{\varepsilon z}\right)z\frac{\varepsilon}{\theta} > 0.
\end{aligned}
\tag{17}
$$

4 Long-run effects of trade liberalization

To obtain the long-run changes of k and a due to an increase in p, we linearize the system in the neighborhood of the steady state $\dot k = \dot a = 0$:

$$
\begin{pmatrix} \partial \dot k/\partial k & \partial \dot k/\partial a \\ \partial \dot a/\partial k & \partial \dot a/\partial a \end{pmatrix}\begin{pmatrix} dk \\ da \end{pmatrix} + \begin{pmatrix} \partial \dot k/\partial p \\ \partial \dot a/\partial p \end{pmatrix} dp = 0, \tag{18}
$$

where the Jacobian $\mathcal{J}$ is negative by the saddle point condition:

$$
\frac{\partial \dot k}{\partial k}\frac{\partial \dot a}{\partial a} < \frac{\partial \dot k}{\partial a}\frac{\partial \dot a}{\partial k}. \tag{19}
$$

From $\mathcal{J} < 0$, (14), (16), (17) and (18) it follows that

$$
\begin{aligned}
\frac{dk}{dp} &= -\frac{1}{\mathcal{J}}\begin{vmatrix} \frac{\partial \dot k}{\partial p} & \frac{\partial \dot k}{\partial a} \\ \frac{\partial \dot a}{\partial p} & \frac{\partial \dot a}{\partial a} \end{vmatrix} = -\frac{1}{\mathcal{J}}\begin{vmatrix} \frac{\partial \dot k}{\partial p} & \frac{\partial \dot k}{\partial a} \\ \frac{z}{z_a}\left[\frac{\varepsilon}{\theta}z_p + a_k\right] - \frac{z_k}{z_a}\frac{\partial \dot k}{\partial p} & \frac{z}{z_a}\left[\frac{\varepsilon}{\theta}z_a - n_a\right] - \frac{z_k}{z_a}\frac{\partial \dot k}{\partial a} \end{vmatrix}\\
&= -\frac{1}{\mathcal{J}}\frac{z}{z_a}\begin{vmatrix} \frac{\partial \dot k}{\partial p} & \frac{\partial \dot k}{\partial a} \\ \frac{\varepsilon}{\theta}z_p + a_k & \frac{\varepsilon}{\theta}z_a - n_a \end{vmatrix} = -\frac{1}{\mathcal{J}}\frac{z}{z_a}\begin{vmatrix} a - \frac{\varepsilon}{\theta}\frac{z_p}{\varepsilon} & -\left(1 + \frac{\varepsilon}{\theta}\frac{1}{\varepsilon}\right)z_a \\ \frac{\varepsilon}{\theta}z_p + a_k & \frac{\varepsilon}{\theta}z_a - n_a \end{vmatrix},\\
\frac{da}{dp} &= -\frac{1}{\mathcal{J}}\begin{vmatrix} \frac{\partial \dot k}{\partial k} & \frac{\partial \dot k}{\partial p} \\ \frac{\partial \dot a}{\partial k} & \frac{\partial \dot a}{\partial p} \end{vmatrix} = -\frac{1}{\mathcal{J}}\begin{vmatrix} \frac{\partial \dot k}{\partial k} & \frac{\partial \dot k}{\partial p} \\ \frac{z}{z_a}\left[\frac{\varepsilon}{\theta}z_k - n_k\right] - \frac{z_k}{z_a}\frac{\partial \dot k}{\partial k} & \frac{z}{z_a}\left[\frac{\varepsilon}{\theta}z_p + a_k\right] - \frac{z_k}{z_a}\frac{\partial \dot k}{\partial p} \end{vmatrix},\\
&= -\frac{1}{\mathcal{J}}\frac{z}{z_a}\begin{vmatrix} \frac{\partial \dot k}{\partial k} & \frac{\partial \dot k}{\partial p} \\ \frac{\varepsilon}{\theta}z_k - n_k & \frac{\varepsilon}{\theta}z_p + a_k \end{vmatrix} = -\frac{1}{\mathcal{J}}\frac{z}{z_a}\begin{vmatrix} y_k - \left(1 + \frac{1}{\varepsilon}\frac{\varepsilon}{\theta}\right)z_k & a - \frac{\varepsilon}{\theta}\frac{z_p}{\varepsilon} \\ \frac{\varepsilon}{\theta}z_k - n_k & \frac{\varepsilon}{\theta}z_p + a_k \end{vmatrix},
\end{aligned}
$$

$$
\begin{aligned}
\lim_{(\theta/\varepsilon)\to 0}\frac{dk}{dp} &= -\frac{1}{\mathcal{J}}\frac{z}{z_a}\lim_{(\theta/\varepsilon)\to 0}\begin{vmatrix} a-\frac{\varepsilon}{\theta}\frac{z_p}{\varepsilon} & -\left(1+\frac{\varepsilon}{\theta}\frac{1}{\varepsilon}\right)z_a \\ \frac{\varepsilon}{\theta}z_p + a_k & \frac{\varepsilon}{\theta}z_a - n_a \end{vmatrix} \\
&= -\frac{1}{\mathcal{J}}\frac{z}{z_a}\frac{\varepsilon}{\theta}\begin{vmatrix} a-\frac{\varepsilon}{\theta}\frac{z_p}{\varepsilon} & -\left(1+\frac{\varepsilon}{\theta}\frac{1}{\varepsilon}\right)z_a \\ z_p & z_a \end{vmatrix} = -\frac{z}{\mathcal{J}}\frac{\varepsilon}{\theta}\begin{vmatrix} a & -1 \\ z_p & 1 \end{vmatrix} \\
&= -\frac{z\varepsilon}{\mathcal{J}\theta}(a+z_p) > 0, \\
\lim_{(\theta/\varepsilon)\to 0}\frac{da}{dp} &= -\frac{1}{\mathcal{J}}\frac{z}{z_a}\lim_{(\theta/\varepsilon)\to 0}\begin{vmatrix} y_k - \left(1+\frac{1}{\varepsilon}\frac{\varepsilon}{\theta}\right)z_k & a-\frac{\varepsilon}{\theta}\frac{z_p}{\varepsilon} \\ \frac{\varepsilon}{\theta}z_k - n_k & \frac{\varepsilon}{\theta}z_p + a_k \end{vmatrix} \\
&= -\frac{1}{\mathcal{J}}\frac{z}{z_a}\frac{\varepsilon}{\theta}\begin{vmatrix} y_k - \left(1+\frac{1}{\varepsilon}\frac{\varepsilon}{\theta}\right)z_k & a-\frac{\varepsilon}{\theta}\frac{z_p}{\varepsilon} \\ z_k & z_p \end{vmatrix} = -\frac{1}{\mathcal{J}}\frac{z}{z_a}\frac{\varepsilon}{\theta}\begin{vmatrix} y_k - z_k & a \\ z_k & z_p \end{vmatrix} \\
&= -\frac{1}{\mathcal{J}}\frac{z}{z_a}\frac{\varepsilon}{\theta}\begin{vmatrix} y_k & a+z_p \\ z_k & z_p \end{vmatrix} = -\frac{1}{\mathcal{J}}\frac{z}{z_a}\frac{\varepsilon}{\theta}\begin{vmatrix} + & + \\ + & - \end{vmatrix} < 0.
\end{aligned}
$$

This result can be rephrased as follows:

Proposition 1 *If status is significant relative to the number of children (e.g. if θ/ε is small enough), then trade liberalization will increase capital k and decrease per capita emissions a in the long run.*

A considerable share of the gains from trade is invested only if the role of status is large. For the rest of the study, we assume that θ/ε is small enough to generate this behaviour.

5 Short-run effects of trade liberalization

Given (16), (17) and (19), it is true for small enough θ/ε that

$$
\frac{\partial\dot{k}}{\partial a} < 0, \quad \frac{\partial\dot{a}}{\partial a} > 0, \quad \frac{\partial\dot{a}}{\partial k} > 0, \quad \frac{\partial\dot{k}}{\partial k}\underbrace{\frac{\partial\dot{a}}{\partial a}}_{+} < \underbrace{\frac{\partial\dot{k}}{\partial a}}_{-}\underbrace{\frac{\partial\dot{a}}{\partial k}}_{+} < 0, \quad \frac{\partial\dot{k}}{\partial k} < 0. \tag{20}
$$

This implies that both singular curves ($\dot{k}=0$) and ($\dot{a}=0$) are decreasing, but the curve ($\dot{k}=0$) falls steeper than the curve ($\dot{a}=0$) [see Fig. 1],

$$
\left.\frac{\partial n}{\partial k}\right|_{\dot{k}=0} = -\frac{\partial\dot{k}}{\partial k}\bigg/\frac{\partial\dot{k}}{\partial a} < -\frac{\partial\dot{a}}{\partial k}\bigg/\frac{\partial\dot{a}}{\partial a} = \left.\frac{\partial a}{\partial k}\right|_{\dot{a}=0} < 0.
$$

Given (16), (17) and (18), the comparative dynamic properties of the system in the (k, a)-plane are the following. Assume first that the system is

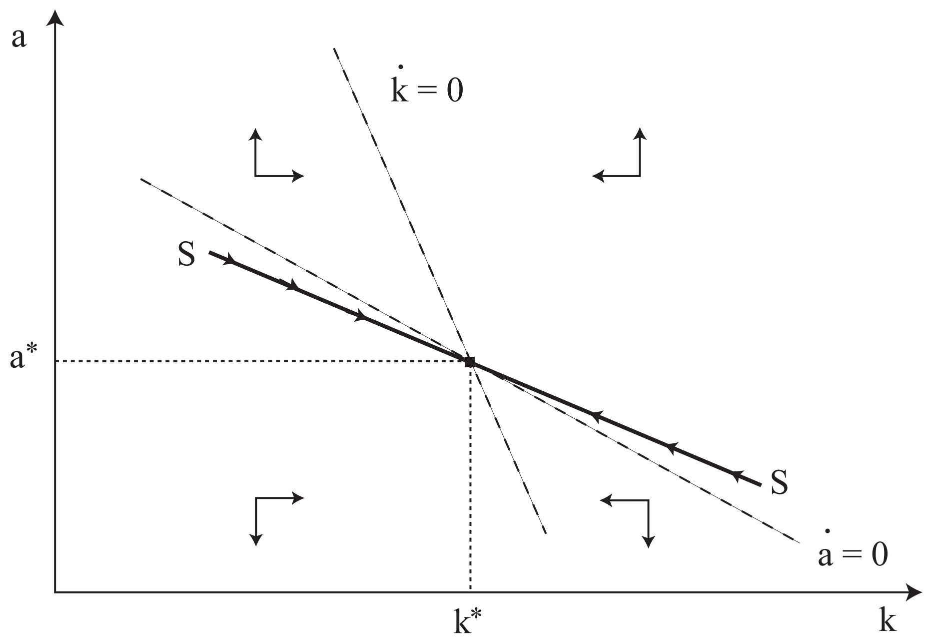

Figure 1: The saddle point

initially in the steady state (k_0^*, a_0^*). Once the price p increases, the steady state moves to (k_1^*, a_1^*). Noting (16), (17) and (20), we obtain that both curves $(\dot{k} = 0)$ and $(\dot{a} = 0)$ shift to the right [Fig. 2]:

$$\left.\frac{\partial k}{\partial p}\right|_{\dot{k}=0} = -\underbrace{\frac{\partial \dot{k}}{\partial p}}_{+} \Big/ \underbrace{\frac{\partial \dot{k}}{\partial k}}_{-} > 0, \quad \left.\frac{\partial k}{\partial p}\right|_{\dot{a}=0} = -\underbrace{\frac{\partial \dot{a}}{\partial p}}_{-} \Big/ \underbrace{\frac{\partial \dot{a}}{\partial k}}_{+} > 0. \tag{21}$$

Given proposition 1, the capital-labor ratio k rises but emissions a fall in the long run, $k_0^* < k_1^*$ and $a_0^* > a_1^*$. From (17) it follows that when p increases, the co-state variable n may jump upwards from a_0 to $\hat{a}$ [Fig. 2].[2] After this, the system evolves along the saddle path SS to the new steady state (k_1, a_1). Thus, the increase in p may raise a in the short run.

Proposition 2 *Trade liberalization (i.e., a higher p) may increase per capita emissions a in the short run, but it definitely decreases these in the long run.*

[2]At the theoretical level, we cannot fully eliminate the possibility that a jumps downwards. In such a case, total saving increases so much that the family consumes less children also in the short run. Because we didn't find any developing country that would have followed such development patterns, we left that case out of Fig. 3.

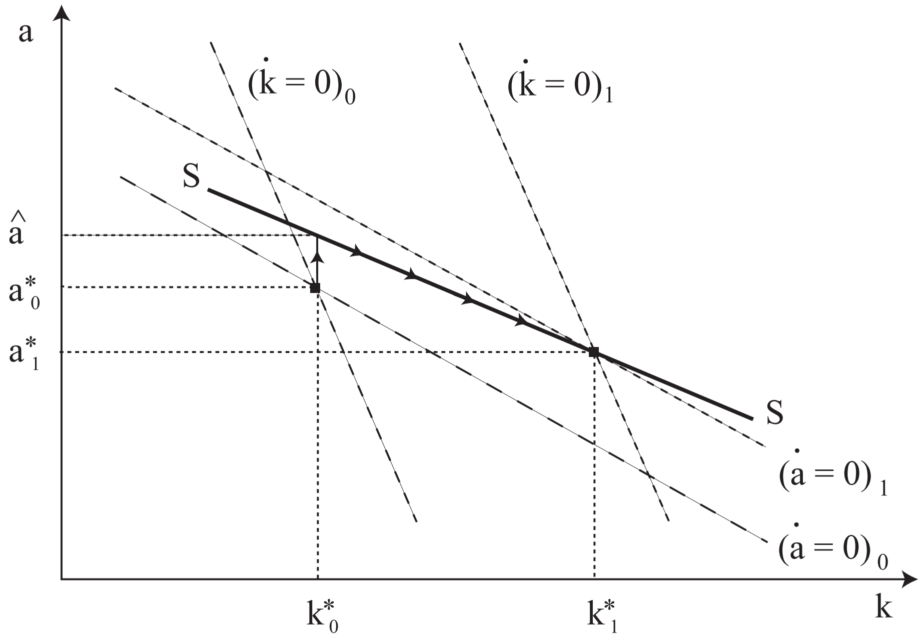

Figure 2: The dynamics of the model

To comprehend these results, consider the effect of the the gains from trade (i.e., a higher export price p) and the role of the Rybczynski theorem. Initially, both the capital stock K and population L are constant while population growth n increases because gains from trade induce an income effect raising the demand for children. Therefore, labor supply $L - qnL$ decreases as people withdraw from production. Hence, per capita capital stock $k = K/L$ is constant but the capital-labor ratio in production, $K/(L-qnL) = k/(1-qn)$, increases. This leads to expansion of the capital-intensive dirty sector and per capita emissions $a = A/L$ increase from a_o^* to $\hat{a}$ [Fig. 2]. In the long run, gains from trade stimulate savings and per capita capital stock k raises from k_0^* to k_1^* [Fig. 2]. As the capital accumulation starts, the capital-labor ratio in production, $K/(L-qnL) = k/(1-qn)$ increases, leading to an increase in wages. With higher wages, people choose to have fewer children, the population growth rate n decreases, people re-enter the labor force and the capital-labor ratio in production, $K/(L-qnL) = k/(1-qn)$ decreases again, falling ultimately below its original level. This downsizes the capital-intensive dirty sector and decreases per capita emissions a from $\hat{a}$ to a_1^*. Obviously, the swelling labor force put wages in pressure but capital accumulation is capable to more than offset this pressure. Hence, population keeps decreasing and may ultimately fall below its post-trade level.

6 Some anecdotal evidence

Has there been any impact of trade liberalization on per capita pollution in developing countries? The model above argues that, in the short run, trade liberalization increases population growth and decreases the labor supply. By the Rybczynski theorem, this expands the capital intensive dirty sector. In the long run, capital accumulation decreases population growth and increases labor supply as parents re-enter the labor force together with their grown-up children. This curbs the dirty sector and a typical EKC path appears.

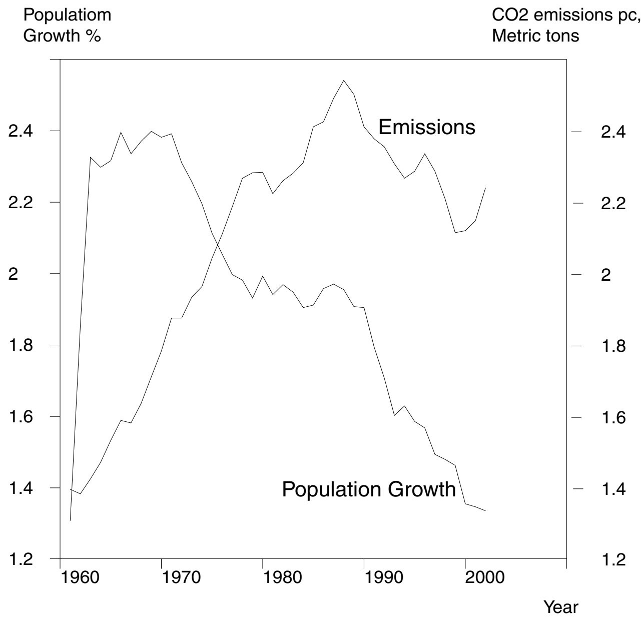

Figure 3: Population growth and per capita pollution measured as per capita CO_2 emissions in the Low and Middle Income Countries. Source: World Bank 2007

Consider now the post-war history of population and pollution in developing countries (Low and Middle Income Countries in the World Bank classification, Figure 3). This shows a fast increase in population growth toward the end of 1960s and a rapid decline soon after. On the other hand, the per capita pollution, measured as CO_2 emissions, peaked approximately one generation later, as predicted by the model.

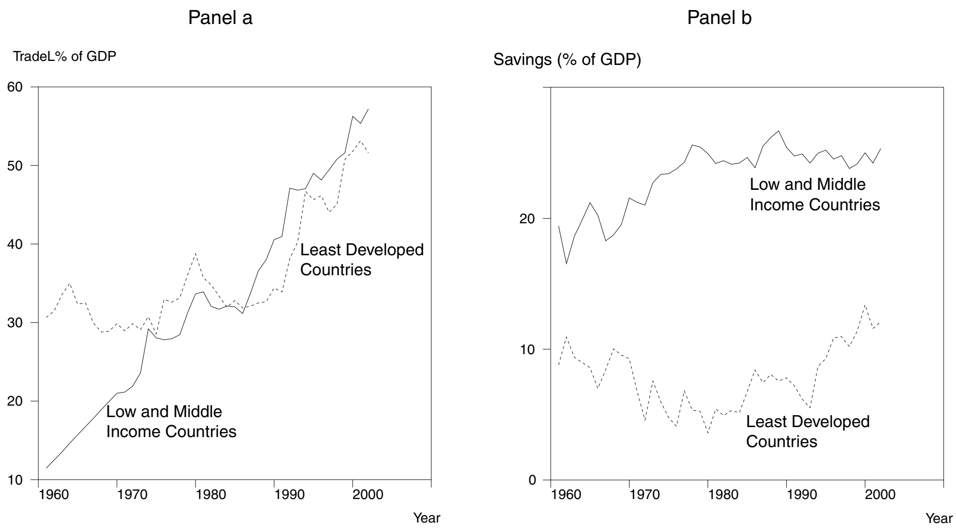

Figure 4: Trade and savings in the Least Developed Countries and in the Middle Income Countries. Source: World Bank 2007

The model above claims that the EKC path is conditional to capital appreciation, i.e., to the status effect. If this effect is weak, gains from trade generate population growth, there is no take-off of investments, and income is low. This, indeed, has been the typical pattern in the Least Developing Countries, where high population growth continued until 1990s, and where the per capita pollution peak is not reached yet. Panel a in Figure 4, however, shows that the Least Developed Countries have not been closed. On the contrary, their trade was initially higher than that in the developing countries on the average but domestic savings have been exceptionally low [Figure 4, panel b] and gains from trade have mainly manifested themselves as demographic growth. These countries have not yet reached the phase in which population growth decreases, labor supply swells, and pollution decreases. The status effect, therefore, may have played a considerable role in the EKC patterns of developing countries.

7 Conclusions

This paper examines per capita pollution in a developing economy by a family-optimization model where children are normal goods in preferences and wealth, as the proxy for status, has a positive effect on welfare. Although developing economies are capital poor, we assume that trade liberalization increases their specialization in the capital intensive dirty good because of lax environmental laws in these countries.

Trade liberalization raises the relative price for exports and generates gains from trade. The outcome of this depends on the significance of the status effect. When this effect is weak, families spend the gains from trade mainly in the consumption of goods and children. This leads to persistent stagnation in investment and long-lasting population growth. When the status effect is strong, a considerable share of the gains from trade is invested. In such a case, population growth first increases but then decreases leading to opposite changes in labor supply. The Rybczynski theorem then indicates that the capital-intensive dirty sector first expands and crowds out the labor-intensive clean sector but ultimately this development pattern is reversed. Consequently, a typical EKC path is obtained: per capita pollution increases at the earlier but decrease at the later stages of development.

This paper concentrates on the EKC, i.e., on the per capita pollution. We argue that per capita pollution decreases below its original level in the long run. The total pollution, however, is of the ultimate interest, at least in those cases where the pollutant is a public good, common to all inhabitants. In spite of the decrease in the per capita pollution, total pollution increases if the decrease of the per capita pollution does not outweigh the still ongoing population growth. Therefore, one may ask which effect trade liberalization has on total pollution. In the presence of the status effect, trade stimulates capital accumulation and rises wages. If this mechanism is strong, population growth may fall below its post-trade level. Hence, it seems likely that trade liberalization also has a favorable effect on the total pollution. Therefore, those developing countries that exercise restrictive trade policies or fail to support domestic savings may be the worst polluters in the future.

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